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Improving the electronic repair capabilities in the fleet.

Brown, Nancy Elizabeth

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL

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CAPABILITIES IN THE FLEET

by

Nancy E. Brown

March 1982

Thesis Advisor: Alan W. McMasters

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Improving the Electronic Repair Capabilities in the Fleet

by

Nancy E. Brown
Lieutenant, United States Navy
B.S., Stephens College, 1973

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Maintenance in the U.S. Navy is officially prescribed to be accomplished by a three-tiered approach: organizational level (ship's force), intermediate level (tenders and shore-based intermediate maintenance activities--SIMAs), and depot level (shipyards). This thesis examines current trends in the utilization of these levels for maintenance of electronic equipment. The major objective was to determine the impact on manpower, training and supply support that an increase in the organizational level's responsibilities would have. An extensive research effort considered all available printed material relating to the maintenance systems currently in use. Interviews with maintenance managers at all levels of command were conducted at U.S. Navy maintenance facilities at Pearl Harbor, Hawaii, San Diego, California, and Norfolk, Virginia. These interviews addressed general maintenance topics as well as specifics on eight pieces of electronic equipment. The major conclusion of this effort is that given adequate training, proper tools and increased supply support the organizational level's capabilities are constrained only by the physical limitations of its vessel.

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I. INTRODUCTION

The U.S. Navy's prescribed three-tiered approach to maintenance accomplishment consists of the organizational level (ship's force), the intermediate level (tenders and Shore Intermediate Maintenance Activities--SIMAs), and the depot level (shipyards). Maintenance actions are identified as either preventive or corrective. Preventive actions seek to prevent failure while corrective actions attempt to repair a failed piece of equipment.

The evolution in electronics from discrete components to integrated circuits has fostered the implementation of a modular replacement maintenance philosophy in the event of failure of equipment for communication, combat and weapons systems. Pursuit of this philosophy complemented the decreasing availability, during the 1970's, of resources. The result of this philosophy has been that the organizational and intermediate levels are limited to the performance of only routine preventive maintenance functions and replacement of failed modules, while all corrective maintenance actions on those modules have become a depot-level-only responsibility. This has threatened, and continues to threaten, both the operational availability and the self-sufficiency of today's naval force. The lack

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of required skills, tools and parts can only lead to a further degradation of these aspects in the fleet.

It is the attempt at prevention of any further degradation that has initiated a reversal to this trend. The impetus is now to return expanded responsibilities and capabilities for corrective maintenance to the organizational and intermediate levels. This thesis examines these trends and the resulting impact on the support establishment. It was motivated by a request from the Naval Electronic Systems Command Detachment, Mechanicsburg (NAVELEXDETMECH), to determine the extent of current corrective maintenance capabilities of the organizational level.

Chapter II examines the three-tiered approach to maintenance and the current trend in the distribution of responsibilities between the three levels within the U.S. Navy. Chapter III reviews the structure of the Navy's current maintenance organization and the roles played by each of the organizations involved. Chapter IV evaluates existing organizational level corrective maintenance capabilities with an emphasis on specific case studies on eight pieces of electronic equipment of interest to NAVELEXDETMECH. Chapter V presents change initiatives which include the Miniature/Microminiature (2-M) Electronic Repair Program, the Automatic Test Equipment (ATE) Evaluation and the Reliability Centered Maintenance (RCM) methodology. Chapter VI provides the conclusions.

Because of the numerous areas that impact on maintenance, this thesis only highlights those in need of review. Further study is required in each area if the U.S. Navy is to adequately equip forces to fulfill its missions.

II. THE LEVELS OF MAINTENANCE

At one time the state-of-the-art electronic equipment utilized on all Navy platforms consisted of tubes, capacitors and resistors. Most of this equipment had very similar construction and could be fairly easily maintained by the average Navy technician of the time. The thorough training in troubleshooting techniques and electronic principles gave the technician the fundamentals necessary to correct failures. It also fostered a feeling of pride in accomplishment and of ownership.

Equipment of this period, with its similarities in construction, permitted a maintenance philosophy that centered responsibility on the individual platforms and encouraged the ultimate in maintenance self-sufficiency. Even though outside assistance was available, its utilization was, by choice, mostly limited to major overhaul periods. The Navy maintenance structure was therefore essentially composed of only two levels: the organizational level and the depot level. Additionally, the evaluation or development of a maintenance concept for new equipment was not required nor was the impact of the maintenance requirements evaluated. However, as electronic systems became more sophisticated and tubes became the dinosaurs of electronics, the impact of new systems began to be felt and the ramifications of

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ignoring the maintenance issues during the development phase forced the development of a Navy maintenance philosophy. This was evidenced by the trend away from shipboard repair toward modular replacement or the "black box" maintenance concept.

The development, during the mid 1970's, of a maintenance concept for the Navy was necessitated by increasingly sophisticated and technically complex systems as well as the decreasing availability of resources. The new constraints on resources affected every phase of Navy life from available dollars for recruiting and training to the availability of fuel for deployments. The attempts to adjust to this austere environment, while the maintenance of the new systems was requiring higher and higher levels of expertise, resulted in the development of a maintenance concept which would consider the need for resources explicitly. This required the identification and inclusion into the first phase of design of the support levels, repair policies, effectiveness measures and logistic support requirements envisioned for the new system. The purposes of the maintenance concept were to:

1. Provide the basis for the establishment of supportability requirements in system/equipment design.

2. Provide the basis for the establishment of requirements for total logistic support.

3. Provide a basis for detailing the maintenance plan and impacts upon the supply concept, training concept, supplier technical services, phased logistic

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> support, transportation and handling criteria, and production data needs. [Ref. 1]

Implementation of the concept was accomplished through the requirements established in MIL-STD-1390A (NAVY), dated 1 April 1974, the military standard for level of repair (LOR) analysis, which was superseded by MIL-STD-1390B (NAVY) on 1 December 1976.

> LOR decisions influence the logistic support cost and system effectiveness of naval material and hence influence the total life cycle cost of ownership. LOR decisions also influence the maintenance plan and the ILS (Integrated Logistic Support) elements necessary to maintain the operational readiness of the hardware system. [Ref. 2]

MIL-STD-1390B requires that the LOR analysis and resulting decisions be initiated during the preliminary design phase and continue until the final hardware design had been determined. The LOR analysis ensures that the most economic maintenance policy for all new systems is developed.

While LOR analysis requirements enhanced awareness of future maintenance needs, the shortages of resources available to provide for the current and projected needs had motivated a reevaluation in 1973 of how maintenance was accomplished. As a consequence of this evaluation, a uniform maintenance program for electronic material was established by the Naval Material Command. It was this policy, published in NAVMATINST 4790.19 of 4 June 1973, that sought relief from decreasing resource availability through design, the premise of which was to remove the responsibilities of repair from the organizational level to the

intermediate and the depot levels. At the same time, savings were sought by lengthening the period between major overhauls. Accomplishment of this included emphasizing preventive maintenance as a means of increasing the mean-time-between-failure and the establishment of mini-overhauls or scheduled intermediate maintenance availabilities.

This brought about, by the mid-1970's, an increased dependence on the intermediate maintenance level. Dependence on the intermediate level was further encouraged by continued decreased manning and capabilities at the organizational level as well as the "black box" concept of the Naval Material Command's uniform maintenance program.

A. MAINTENANCE CATEGORIZATIONS

By 1974, the division of labor between the three levels of maintenance severely restricted the organizational level's area of responsibility. This is evidenced by the following description of the three levels of maintenance taken from NAVMATINST 4700.4B of 12 August 1974.

> Organizational Maintenance. That maintenance which is the responsibility of and performed by using organizations on their assigned equipment. Its phases normally consist of inspecting, servicing, lubricating, adjusting and the replacing of parts, minor assemblies and sub-assemblies.
>
> Intermediate Maintenance. That maintenance which is the responsibility of and performed by designated maintenance activities for direct support of using organizations. Its phases normally consist of calibration, repair or replacement of damaged or unserviceable parts, components, or assemblies; the emergency manufacture of non-available

parts; and providing technical assistance to using organizations.

Depot Maintenance. That maintenance which is the responsibility of and performed by designated maintenance activities to augment stocks of serviceable material and to support organizational maintenance and intermediate maintenance activities by the use of more extensive shop facilities, equipment and personnel of higher technical skill than are available at the lower levels of maintenance. Its phases normally consist of inspection, test, repair, modification, alteration, modernization, conversion, overhaul, reclamation or rebuild of parts, assemblies, sub-assemblies, components, equipment end items and weapon systems; the manufacture of critical nonavailable parts; and providing technical assistance to intermediate maintenance organizations, using and other activities. [Ref. 3]

This same basic division of responsibilities between maintenance levels was perpetuated by the Fleet Commanders in Chief. The following was taken from COMNAVSURFLANTINST 9000.1 of 12 June 1975.

Organizational (Shipboard) Level Maintenance. Organizational level maintenance is that maintenance level which is the responsibility of and performed by the ships force on assigned equipment. The individual ship shall be self-sufficient to the maximum degree. The planned maintenance sub-system, described in the Maintenance and Material Management (3-M) Manual defines the minimum preventive maintenance program to be carried out on board the individual ship. It is a command responsibility to ensure that this maintenance is effectively planned, scheduled and accomplished.

Intermediate Level Maintenance Activity (IMA). Intermediate level maintenance is that maintenance which is normally performed by Navy IMA personnel on tenders, repair ships, aircraft carriers, fleet support bases, and Shore Intermediate Maintenance Activities (SIMAs). It normally consists of calibration, repair or replacement of damaged or unserviceable parts, components, or assemblies; the emergency manufacture of unavailable parts; and providing technical assistance to using organizations.

Depot (Shipyard) Level Maintenance. Depot level maintenance is that maintenance performed by industrial activities

> on material requiring major overhaul or a complete rebuilding of parts, assemblies, sub-assemblies, and end items, including the manufacturing of parts, modifications, testing and reclamation as required. This is normally accomplished on ships at commercial facilities or naval shipyards, including ship repair facilities, during restricted availabilities, technical availabilities and regular overhauls. [Ref. 4]

Maintenance, as defined by the Navy is ". . . action taken to retain material in a serviceable condition or to restore it to serviceability . . ." [Ref. 5]. This leads to a further categorization of maintenance into preventive and corrective maintenance. Preventive maintenance is defined as planned maintenance consisting of the periodic performance of tests, inspections, cleaning and renewing of operating consumables (i.e., filters or lubricants) on operable equipment. Corrective maintenance is the accomplishment of repairs to inoperable equipment for the purpose of returning them to operable condition. This includes diagnosis of the casualty, disassembly, purchase and installation of repair parts, reassembly and test. [Ref. 6]

The breakdown of responsibility listed earlier restricts the lowest or organizational level to conducting actions to retain material in a serviceable condition (preventive maintenance) while it is the intermediate and the depot levels that are restoring equipment to serviceability (corrective maintenance). This division between the activities of the organization and the other two levels was at one time viewed as an answer to a shortage of resources. "Black

box" technicians required significantly less training and could support a greater number of equipments. The problem with corrective maintenance being restricted to the higher levels of maintenance is that technical self-sufficiency is degraded. That is not considered as desirable by the Commander in Chief U.S. Pacific Fleet (CINCPACFLT) who, in a letter dated 25 July 1978, stated that, "It is Navy policy that fleet activities be technically self-sufficient to the maximum extent practicable." [Ref. 7]

B. TRENDS IN MAINTENANCE PHILOSOPHY

Recent correspondence indicates that increasing emphasis is being placed on restoring the capabilities of the organizational level. In particular, both Fleet Commanders support the need to restore self-sufficiency to the fleet. Examples of this shift are contained in their comments to the draft Navy Training Plans (NTPs), dated 1981, for four new systems (AN/KG-84, AN/KW-46, AN/USC-34 and AN/SPA-25); all of which epitomize the ultimate in a "black box" maintenance concept. In the case of the AN/KG-84, organizational level maintenance was not even mentioned in the NTP. The other three systems specify component replacement as the only organizational requirements. All four totally disregarded the intermediate level resulting in a two-level maintenance structure, organizational and depot. The comments of both Fleet Commanders stressed inclusion of the

organizational and intermediate levels in the maintenance plans. The Commander in Chief U.S. Atlantic Fleet (CINCLANTFLT) was the most specific on this issue.

> The proposed concept of module replacement only at the organizational level has proven largely ineffective with other electronics systems due primarily to non-sparing of modules and printed circuit boards (PCBs). The capability in the fleet to repair PCBs has been established by necessity through installation of miniature and microminiature (2M) electronic repair stations with appropriate numbers of trained personnel. These personnel and station equipments are inspected annually to ensure a continuing capability to do depot quality work. Fleet IMAs are also being equipped with automatic test equipment (ATE) for digital PCBs which allow go/no-go testing and fault isolation.
>
> In view of the above it is requested that all low cost LINK 11 equipment be supported on board ship with documentation and piece parts to support emergency 2M repair, and that Test Program Sets (TPSs) be developed for ATE located at IMAs to allow for full fault isolation and repair of digital PCBs. [Ref. 8]

Similar comments have been submitted on other training plans that neglected the organizational or intermediate level capabilities. However, the most recent statement of policy from the Naval Material Command and the Naval Sea Systems Command continues to staunchly support repair of all 2M PCBs and modules, regardless of Source, Maintenance and Recoverability (SM&R) codes, by the depot level and to limit the intermediate and organizational levels to normal repairs of only those PCBs and modules specifically coded for their level. This limitation almost completely excludes these two levels from repair due to the very few numbers of boards coded in this manner. [Refs. 9 & 10]

This difference in philosophy collided during the Navy Training Plan Conference held on 8 December 1981 for the Radar Display and Distribution System (RADDS). As had been the practice with other Navy Training Plans (NTPs), CINCLANTFLT submitted comments regarding the inclusion of the intermediate level into the maintenance plan as well as extending repair to the piece part level. The conflict arose when the conference chairman ruled against such a revision.

> . . . the NTPs do not determine the maintenance philosophy, but the maintenance philosophy drives the type of training. Therefore, as the maintenance has been set by CNO/CHNAVMAT for all systems to the circuit card level or lowest replaceable unit (LRU), that is the planned maintenance philosophy for the RADDS system. Under the approved maintenance plan there are two levels, organizational (circuit card replacement) and depot (repair circuit cards). IMA Level repair does not exist in the approved CNO/CHNAVMAT surface fleet maintenance plan . . . . [Ref. 11]

The recourse taken by CINCLANTFLT was to confront the Chief of Naval Operations (CNO)/CHNAVMAT directly with a request to change the maintenance philosophy. It was CINCLANTFLT's contention that component level repair of modules only by the depot, and only for modules costing more than $500, is neither cost effective nor operationally acceptable. "To throw away a $450 board because of a defective $3.95 integrated circuit is foolish. To reduce the combat capability of a $100,000,000 ship because the closest replacement module is undergoing repair at a depot is criminal, but both examples occur on a regular basis because of

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today's depot-only repair concept" [Ref. 12]. Recommended concept changes included:

> Organizational level. Authorize onboard repair of modules where replacement modules are not immediately available. Provide ships with schematics of modules to enable onboard fault isolation as required. Also, provide basic kit with piece parts needed to make repairs.
>
> Intermediate level. Authorize to screen all suspect modules using ATE, return good PCBs to ship and repair defective boards. [Ref. 13]

Implementation of CINCLANTFLT's recommendations would mesh the systems command's end product with the concept of maintenance levels as defined by the Office of the Chief of Naval Operations (OPNAV) in OPNAVINST 4700.7F of 28 September 1981. This policy statement specifically includes corrective maintenance as an organizational level responsibility and stresses the need for each platform to be self-sufficient to the highest degree obtainable.

> a. Organizational (Shipboard) Level Maintenance
> The first level of maintenance is the Organizational level consisting of the ship itself and the sailors on board the ship. Organizational level maintenance is that corrective and preventive maintenance accomplished by the ship's crew. . . . The individual ship shall be maintenance self-sufficient to the degree achievable within manpower and facility constraints.
>
> b. Intermediate Level Maintenance
> The next level of maintenance is the Intermediate level consisting of Tenders, Repair Ships and Shore Intermediate Maintenance Activities wherein Navy personnel with specialized facilities and training accomplish intermediate level repair work. . . . It normally consists of calibration, repair or replacement of damaged or unserviceable parts, components or assemblies; the emergency manufacture of unavailable parts; and providing technical assistance.

c. <u>Depot Level Maintenance</u>

> Depot level maintenance is that type of maintenance generally requiring a greater industrial capability than possessed by either organizational or intermediate level activities. It consists of that maintenance performed by shipyards, either commercial or Navy, on equipment requiring major overhaul or complete rebuild of parts, assemblies, subassemblies, end items, and complete platforms including manufacture of parts. . . . The only work to be scheduled for accomplishment by depot level maintenance activities will be because of insufficient time or manpower or because it is beyond the capabilities of these fleet maintenance activities . . . . [Ref. 14]

This return to an emphasis on an organizational level performing both preventive and corrective maintenance in no way entails deemphasizing the intermediate or depot levels but strives only to alleviate a complete dependency on the latter for corrective maintenance. This action will increase the purview of the organizational level and will encourage a partner type relationship between all three levels. This will enhance the probability that problems will be resolved at the lowest possible level, significantly increase the attainable degree of self-sufficiency and increase the efficiency of the three-tiered maintenance approach. This approach encourages a progression of capabilities with the depot level truly performing only those tasks requiring an industrial capability.

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III. THE STRUCTURE OF THE NAVY'S MAINTENANCE ORGANIZATION

The current organizational structure for maintenance involves a myriad of commands, each having unique responsibilities and motivations for directing maintenance policies and procedures. These foster duplication of effort, multiplicity of philosophies and policies, a lack of a coordination focal point and the absence of authority for enforcing or monitoring any or all of the policies promulgated. The players are so varied that the maintenance arena has become a classic example of the left hand not knowing or, in some instances, not caring what the right hand is doing.

This is evident in the divergence from published Navy maintenance policy that the NAVMAT organization has pursued. As stated previously, OPNAVINST 4700.7F of 28 September 1981 (which has in previous issues and continues to be the vehicle for promulgating Department of Defense (DOD) policy regarding maintenance established by DOD Directive 4151.16 of 30 August 1972) clearly defines the organizational level maintenance responsibilities to include corrective maintenance. However, NAVMATINST 4790.19 of 4 June 1973, and NAVSEAINST 4790.17 of 7 May 1980, both limit repair at the organizational and intermediate levels in favor of depot level repair. The subtlety of accomplishing this violation of policy is directly related to the faulty

economic evaluation of a proposed level of repair and the subsequent SM&R coding.

This divergence is reinforced by the chasm that separates the goals of each organization. OPNAV represents the operational goal of unit self-sufficiency while NAVMAT represents the support side which is driven solely by system support costs. The operators' world is one of immediacy concerned only with the here and now while the support commands are planners concerned with the future. This difference in environments further separates their respective goals.

The surface community exhibits two separate organizations, each designed to operate under different conditions, "the operational establishment which is organized for a wartime environment, while the support establishment is organized to operate in a peacetime environment" [Ref. 15]. Understanding of the surface communities' weaknesses in this area requires an examination of the commands involved in maintenance and their roles.

A. MAINTENANCE ORGANIZATIONS

The only organization that has overall responsibility for maintenance is the Chief of Naval Operations (CNO). The remaining commands are only responsible for a specific portion of the maintenance pie. The supporting systems commands, under the direction of the Naval Material Command

(NAVMAT), include the Naval Sea Systems Command (NAVSEA) and the Naval Electronics Systems Command (NAVELEX). The operational side consists of the staffs of the Fleet Commanders in Chief, the number fleet commanders, the Type Commanders (TYCOMS) and the units themselves. Discussion of the unit level's role is the subject of the following chapter, and will not be included here.

1. Naval Material Command

NAVMAT was chartered to coordinate and oversee the workings of the systems commands. The purpose of its creation was to provide a central point of coordination, unification and support. However, this has not been evidenced in the maintenance area. NAVMAT has been neither a coordinator nor a director. The relationship, based on tradition that has long existed between the systems commands and their respective OPNAV sponsors is such that NAVMAT has been almost totally excluded. The establishment of NAVMAT has been viewed as another layer of bureaucracy which, more often than not, is circumvented.

2. Naval Sea Systems Command

As one of the systems commands under NAVMAT, NAVSEA holds the bulk of the responsibility for total ship maintenance. It is NAVSEA that manages the designing and acquiring of a new class of ships. This responsibility is designated to a Ship Acquisition Project Manager (SHAPM). Included in the tasks of a SHAPM are the projection of the

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support requirements and the development of a maintenance and support plan.

Once the ship is delivered to the fleet, the maintenance planning and evaluation responsibilities are transferred to a NAVSEA Ship Type Directorate where a Ship Logistics Manager (SLM) is assigned. The SLM's are typically responsible for more than one ship class and must divide their available resources between not only the classes but the many functions they are assigned responsibility for. The majority of their resources are used in the alteration or updating of hull, mechanical and electrical equipment.

Assisting the SLM's in the planning and development of alterations and overhaul packages are the Planners and Engineers for Repairs and Alterations (PERAs). The PERAs serve as a coordinating link between the operational and support establishments.

NAVSEA also manages surface and submarine weapons system acquisition, maintenance programs, and alterations and, in conjunction with the Naval Ship Engineering Center (NAVSEC), performs engineering and technical analysis.

Finally, the operations of the Navy shipyards, which are the primary facilities where Navy ships are overhauled, and the Navy Supervisors of Shipbuilding (SUPSHIPS), who administer contracts for work performed by private yards, are overseen by NAVSEA. This includes providing administrative services to the yards, long-range overhaul

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scheduling, and managing distribution of work among the yards. [Ref. 16]

3. Naval Electronics Systems Command

NAVELEX is responsible for the procurement and support of electronic equipment, particularly exterior communications, navigation and intelligence electronics. NAVELEX oversees all maintenance-related engineering activities, including securing support for corrective maintenance and developing technical alterations. Improvements to electronic equipment may be accomplished during major ship alterations or through field changes designed to be made by the organizational level. [Ref. 17]

4. Fleets and Type Commanders

The entire operational side of the U.S. Navy performs maintenance management functions. The fleet commanders set policies and procedures, allocate funds and other resources among the TYCOMs and act as fleet advocates with OPNAV. The numbered fleet commanders handle day-to-day logistic needs of their ships while the TYCOMs are responsible for ensuring the resolution of a given ship's maintenance problems.

TYCOM staffs assist in corrective maintenance problems by securing technical assistance. They oversee repair work performed in intermediate maintenance activities and they plan and fund major work packages to be performed by shipyards. [Ref. 18]

5. <u>The Fourth Level of Maintenance</u>

The failure to provide adequate maintenance planning has resulted in the need for a type of maintenance assistance that is outside the purview of the three-tiered approach. Technical Assistance (TA), promoted initially by the hardware systems commands, fills this void by providing onboard technical support to the ships by highly qualified military, civil service or contractor personnel. The services of TA's include troubleshooting malfunctioning or inoperative equipment, providing advice, instruction and training to the ship's crew; and providing assistance to ship's force for adjusting, tuning or grooming equipment in preparation for deployments or exercises. This type of assistance does not fall under one of the other three categories (organizational, intermediate, or depot) because it is an off-ship repair system that goes to the ship and does not require any special equipment beyond that held by the customer.

TA is provided by a host of activities. There are two levels of TA; that provided by the operational or the fleet chain of command and that provided by the systems commands.

On the fleet side, TA is provided by Mobile Technical Units (MOTUs). MOTUs are shore-based commands headed by Officers-in-Charge. The MOTU organization was established by the CNO in 1962, through the merger of Mobile Ordnance

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Service Units and Mobile Electronics Technical Units. The objective was to increase the reliability and efficiency of fleet electronics and weapons systems by providing technical assistance and training to shipboard personnel. Each MOTU is staffed with a cadre of versatile and highly skilled senior Navy technicians augmented by civil service personnel. MOTU staffs are also augmented with civilian Contractor Engineering and Technical Services (CETS) personnel (and, hence, the MOTU's became recipients of a form of TA). While the fleet commanders fund the operating costs of the MOTU, funding for the CETS personnel is provided by the respective systems command.

Outside the operational chain of command, TA is provided through the Direct Fleet Support (DFS) program. These technical services are defined by NAVMATINST 4350.13 as "those services associated with the installation, operation and maintenance of aircraft and shipboard weapons, equipments and systems and performed by in-house and contract personnel qualified and trained in engineering and technical disciplines." Included are Engineering and Technical Services (ETS) which provide advice, instruction and training in the installation, operation and maintenance of equipments. ETS provided by Navy military and civil service personnel are termed NETS and those performed by commercial or industrial companies are the CETS mentioned earlier.

Both NAVSEA and NAVELEX support field activities for the purpose of providing TA.

NAVSEA supports the Naval Sea Support Centers (NAVSEACENs). These centers represent NAVSEA in designated geographical areas in matters of technical support of ships systems under their cognizance to ensure adequate fleet readiness. NAVELEX provides TA through NAVELEX systems Engineering Centers (NAVSECs). These centers are involved with life-cycle support of existing equipment and engineering design and acquisition of new equipment.

The problems associated with the numerous organizations providing technical assistance are the same as those caused by the lack of an overall maintenance structure. The absence of coordination coupled with an apparent inability to pursue a common objective further degrades system-wide maintenance effectiveness. Finally, TA services are often the same as many of the services available from the intermediate level facilities and the MOTU's. This duplication was the subject of a Pacific Fleet study to review DFS in the Pacific Basin. The resulting recommendation of this 1978 study was to eliminate DFS functions from NAVSEA and transfer all associated resources to the fleet [Ref. 19]. However, the NAVELEX TA services were not included in the proposed transfer. So while consolidation of some of the services would be accomplished, there would

still be no single organization responsible for or coordinating the use of technical assistance.

B. AN ADDITIONAL DIMENSION

The Atlantic and the Pacific fleets differ in maintenance philosophy. The Pacific structure tends toward institutionalization of maintenance. Directly responsible to the Commander in Chief is a quasi-TYCOM, LOGPAC, which is responsible for all shorebased intermediate maintenance activities. LOGPAC serves as the focal point for the shore side of Pacific fleet maintenance efforts but does not incorporate the afloat side. The latter area of responsibility is placed at a lower level; the respective squadrons or group staffs which report to the TYCOMs. In contrast, all maintenance assets in the Atlantic fall under the auspices of the largest TYCOM (SURFLANT) and management is accomplished by representative Readiness Support Groups (RSGs) in each major port. The responsibilities of the RSGs include coordinating requests for assistance from fleet units. However, this role, as stipulated in the RSGs mission statement, is not supported by other fleet instructions delineating procedures to be followed when requesting assistance. For example; COMNAVSURFLANTINST 9000.1, instructs the unit to contact organizations directly when in need of assistance. If ships company and the MOTU are both unable to provide assistance then as a last resort, a

request is submitted to the RSG. This often results in the ship requesting assistance from more than one source and representatives of all sources arriving to provide assistance. This implicit lack of support of the RSG by SURFLANT encourages even further disorder in the delivery of technical assistance.

Although in the best position to provide it, current fleet organizational structures do not exhibit the requisite capabilities for coordinating and supporting increased organizational maintenance and intermediate level activities. Maintenance activities should be consolidated into one chain of command within the fleets to provide coordination and the most effective utilization of assets. This consolidation would reduce the duplication of skills and enhance optimal distribution of the workload.

C. SUMMARY

This overview of the current maintenance structure clearly supports the need for change. The elements required to provide the lacking coordination do exist. The strengthening of the NAVMAT organization, or establishment of some similar group, to coordinate and enforce the pursuit of a single maintenance concept would enhance the systems command's final product. This coupled with an increased emphasis on bridging the gap between the operators and the planners would solidify a one Navy maintenance concept.

The resolution of the "conflict" between a need for self-sufficiency and the need for economic systems acquisition must support the acceptance of organizational level maintenance, as defined by OPNAVINST 4700.7F, to include corrective as well as preventive maintenance functions.

IV. ORGANIZATIONAL LEVEL CAPABILITIES

Organizational level capabilities hinge on the quality of training, available resources (personnel as well as spare parts) and the maintenance policy directed. Increasing the organizational level's role will greatly impact each of these areas. Implementation of the current trend in maintenance philosophy requires an evaluation of what adjustments will be needed. Opponents of this trend argue that today's average Navy technician is probably not capable of mastering the skills required to accomplish the envisioned organizational level repair and that, even if he/she could, it is not cost effective to invest the necessary dollars to provide the additional training needed to develop these skills.

In many cases a cursory economic analysis would probably give credence to such a claim. However, in the case where the defense of a nation is at stake, a cursory economic analysis neglects the most important factor, operational availability.

Regardless of the tested reliability of a system, when it fails it must be repaired. Reliance on a "black box" maintenance concept with only depot level support reduces the obtainable degree of self-sufficiency. During peacetime operations the inability to restore a failed system may not

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be associated with severe consequences. But under other than peacetime conditions the same failure may be catastrophic. In essence, the war might be lost for want of one printed circuit board. When deployed, the technician's priority should be to keep the equipment operational no matter what the maintenance plan details. The peacetime disregard for this fact has resulted in a level of skills which are insufficient to do the needed repairs. If such were attempted, the consequence could possibly lead to the equivalent of 10 years of wear or even more costly damage. Weighing this cost plus the cost of decreased operational availability against the cost of increasing the organizational level's capabilities should easily lend support to the desirability of the latter. With this contention in mind, the impacts on training and resource availability will be examined.

Since Navy electronic equipment is rapidly becoming predominately microelectronic, increased repair capability at the organizational level will be centered on the repair of circuit boards or assemblies involving or containing integrated circuits. This repair capability has been titled the Miniature/Microminiature (2M) Electronic Repair Program.

The Navy consists of three different platform types; air, submarine and surface. The first, air, has taken the lead in reliability-centered maintenance techniques and 2M repair by the intermediate level. Because of this advanced

state, no further discussion of this community's maintenance policy is deemed necessary except to emphasize that expanded responsibilities at the organizational and intermediate levels have been implemented successfully in this community since approximately 1970. [Ref. 20]

The submarine and surface communities adopted a different approach to these technological advances. Although the modular replacement philosophy may not have been a planned approach it was a partial solution to many of the pressures of the early 1970's. This theory was voiced by Mr. Genovese, NAVMAT-04B, on 25 July 1980:

> There was no 'decision' to go to modular replacement, rather it was the technology drive toward more and more capability and sophistication supported by the semiconductor industry combined with the pressures to reduce ship manning. Additionally, production techniques had to change as the technology moved from discrete components to transistors to integrated circuits to large scale integration. So, it was not a conscious, deliberate move but an evolution in a world of competing pressures. [Ref. 21]

Although both communities adopted a modular repair philosophy, there are major differences in the methodology. Because of the obvious differences in size and operational requirements, the relationships between the surface unit and its IMA and the submarine and its IMA bear little resemblence to each other. The submarine repair requirements closely resemble those of the air community. When deployed, the primary task of all personnel is watchstanding. Submarine organizational level capabilities are limited to modular replacement by the characteristics inherent to the

platform. Space and personnel are not available to accomplish electronic repair; this becomes the responsibility of the IMA (Tender). As a consequence, a definite division of roles exists between the organizational level and the intermediate level in the submarine community. The submarine tender has the capability to repair electronic equipment and is stocked to support unit level parts requirements.

In contrast, the relationship between a surface ship and its tender or a shore IMA is not clearly defined. The repair capabilities of a surface ship are bound only by personnel limitations. The intermediate level usually has a wider spectrum of specific skills or NECs (Navy Enlisted Classifications) and acts as a supplement to the unit level rather than a separate entity.

Improvement of the organizational capabilities in the submarine community are not viewed as an issue and will not be addressed. However, the issues of training and resource availability which will be discussed in conjunction with increased unit level capabilities in the surface community are, in general, pertinent to the submarine community and improvements should be equally beneficial.

One of the initial objectives of this thesis was to investigate, at the request of the NAVELEX Detachment, Mechanicsburg, the organizational and intermediate level capabilities with regard to eight specific pieces of electronic equipment. Through on-site visits and interviews

with maintenance personnel from all levels at Pearl Harbor, Hawaii, San Diego, California, and Norfolk, Virginia, spanning both the Atlantic and the Pacific fleets, the related existing capabilities and weaknesses were identified.

Discussion of these findings will commence with the common problems, which were highlighted above, of personnel shortages, lack of adequate parts support and inadequate training. This discussion will be followed by the individual case studies.

A. TRAINING AND RESOURCE AVAILABILITY

Manpower and money limitations, as well as a rapidly changing technology, have induced the modular replacement philosophy of maintenance. Training to replace boards has resulted in up to a 60 percent reduction in some school lengths over that of the preboard era. Training of basic skills and troubleshooting techniques, both of which are required to do piece part repair on these boards, would obviously increase school lengths with a corresponding significant cost increase. However, it is the opportunities lost to save these dollars that must be analyzed.

Currently, the number of repairs attempted at the unit level are directly proportional to the technician's motivation factor. Regretfully, the highly motivated technician may soon become very disillusioned. Having been sent to the fleet unequipped with the basic skills required to make

repairs, the extra effort exerted may do no more than increase frustration and discourage the putting forth of that little extra. The cost of this is job dissatisfaction and eventual loss to the Navy of the technician.

Not all the equipment in the fleet is digital with integrated circuits. Analog, discrete transistors and tubes will continue to be used for some time to come. However, today's technician is in no way prepared to work on this type of equipment. The return to teaching basic electronic skills would more adequately prepare the technician to handle repairs regardless of the technology of the equipment.

A high degree of specialization is also prevalent in today's Navy. This specialization has reached the point where one system may require several specially skilled technicians. Disadvantages of this degree of specialization are not only limited to the high cost of separate training sequences, but also, as observed by the Manpower System Study team of the Maintenance System Development Program (which is addressed further in Chapter V) in August 1977, ". . . this specificity is highly susceptible to obsolescence and complicates the assignment process. In addition, ship configurations are sufficiently different so that successive ship tours are likely to present the individual with equipment different from that for which he was trained." [Ref. 22]

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Another shortcoming of the modular replacement philosophy is the lack of supply support. The greater the reliability of a system the greater the probability that the part will not be available in the supply system when you need it. This encourages cannibalization and hoarding, both of which further degrade the effective operation of this system. The overwhelming opinion in the fleet is that the supply system does not adequately support modular replacement and circumvention of the system is required to obtain any level of adequate support. The weakness of this system has been compounded by higher-than-expected random failure rates and a multiplicity of circuit boards. A stock system based on demand history can not possibly support today's state-of-the-art equipment as reported by the NAVMAT Modular Philosophy Study on 1 July 1981:

> When faced with inoperative equipment and no readily available supply support, ships force will attempt repair--even if ill-equipped and insufficiently trained. Modularity and Shop Replaceable Unit (SRU) design philosophy appears to be nearly universal for maintenance of new shipboard combat, control and communications equipment. These systems were generally not intended to be repaired on board beyond the removal and replacement of component modules. The number of different modules in each system combined with infrequent and random module failures, however, makes the stockage of adequate replacements based on demand history very difficult. The result is often logistic delays and reduced system availability. [Ref. 23]

B. CASE STUDIES

The results of the following case studies highlight the problem areas addressed previously, as well as the poor flow

of information that exists today. The case study format will be: (1) a statement of the problem as perceived by NAVELEXDETMECH, (2) a summary of the interviews with knowledgeable maintenance personnel; this serves as background information leading to, (3) a consensus of the fleet for a recommended resolution of the problem.

1. AN/WRR-7

PROBLEM: The AN/WRR-7, more commonly known as the VERDIN, is a submarine radio receiver. It is a relatively old design, with an Equipment Dictionary (EDICT) entry date of 1969, and contains over 100 different circuit boards, only six of which are carried as authorized spares. With that many modules, the system would appear to be difficult to troubleshoot, particularly since the self-diagnostics can only go down to identifying a group of two or three modules. With only six spares available, one of which might not even be the one needed, it was suspected that a large demand would exist for replacement boards. However, this has not been the case. The question then became, "Are the boards being obtained from unauthorized sources?"

BACKGROUND: Discussions were held with the following personnel:

NAME	ORGANIZATION	FLEET
ETCS (SS) P. Eichel	SUBMARINE GROUP 5	PACIFIC
SNC (SS) D. Holtom	SUBMARINE GROUP 5	PACIFIC
ENS B. Manning	USS McKEE (AS-41)	PACIFIC
LT G. R. Geithmann	FLTRACEN NORFOLK	ATLANTIC
RMC (SS) W. Holman	MOTU-2 NORFOLK	ATLANTIC

The concensus was that the Verdin is a very reliable piece of equipment with few problems. The diagnostic tapes are very good and fault isolation is easily accomplished. After the problem has been narrowed down to three boards, a simple swapping procedure is utilized to identify the bad card. This procedure is aided by the duplication of cards that exists, which permits cards to work in over 25 locations. It is also possible to maintain operation of the Verdin without all of the cards being 100 percent functional.

Since introduction of the Verdin into the fleet, field changes have resulted in correction of initial design problems and weaknesses. Examples include a defective PM-5 card and the magnetic programming tape unit. The original connectors on the unit were very fragile and easily damaged. The high failure rate of this unit was not predicted and was the cause of extended downtime. However, a field change that strengthened the connectors partially corrected this problem and, coupled with proper care, the new connectors have significantly decreased the failure rate.

The defective PM-5 card caused the crypto alarm light to stay on, but in no way interfered with the actual operation of the equipment. Replacement of this PM-5 card, by Collins Radio, is currently underway. An interesting fact is the way in which this problem was finally documented. Although existing since introduction, the fact that operations were not hindered resulted in the fleet ignoring

the crypto alarm light malfunctioning. It was not until the commissioning of the USS San Francisco (SSN-711), approximately twelve years after fleet introduction of the Verdin, when the Commanding Officer refused to sign release from the shipyard until the crypto alarm light malfunction was corrected, that the faulty PM-5 card was discovered.

It is expected that new problems will begin to surface, such as failure of the programming tape itself, from normal wear-and-tear as age begins to take its toll.

RECOMMENDATION: Fault isolation would be enhanced if extender cards were available. These cards attach to the actual equipment cards and enhance accessibility to the circuit boards. The technician can easily see the extender card which is diagnosing what the respective circuit board is doing. The need for these cards is particularly great at the intermediate maintenance level.

2. AN/BRD-7

PROBLEM: The AN/BRD-7 is a submarine radio; its antenna is connected through a fitting on the ship's hull. Because of this connection it is obvious that the organizational level can not do repairs while deployed so the question of the proper level of maintenance was addressed.

BACKGROUND: Discussions were held with the following personnel:

NAME	ORGANIZATION	FLEET
ENS B. Manning	USS McKEE (AS-41)	PACIFIC
Mr. J. B. Williams	NESEC San Diego	PACIFIC
CDR J. Burritt	USS EMORY LAND (AS-39)	ATLANTIC
LT B. Welch	MOTU-2 NORFOLK	ATLANTIC

It was agreed on that, in view of the hull connection and the exterior cables, the BRD-7 can not be worked on at sea. Any rework needs a crane which further supports maintenance accomplishment at the intermediate level. It was noted that this equipment has some chronic problems but none that are difficult to repair. Therefore, intermediate level repair is accomplished to the extent allowed. The requirement currently exists for any internal antenna maintenance to be done by the depot. It was suggested that, with the appropriate documentation, authorization and parts, the intermediate level could do any required repairs.

RECOMMENDATIONS: Revise the maintenance plan to allow the intermediate level to do all repairs on the AN/BRD-7 antenna. Provide the appropriate documentation and parts to the IM level.

3. AN/WLR Family

PROBLEM: NAVELEX fleet maintenance representatives support repair by the organizational level. The question is whether or not the capability exists at the organizational level and, if so, to what level can repair be accomplished.

BACKGROUND: Discussions were conducted with the following personnel:

NAME	ORGANIZATION	FLEET
LCDR R. Tudor	SIMA, PEARL HARBOR	PACIFIC
ENS B. Manning	USS McKEE (AS-41)	PACIFIC
Mr. E. Miller	NESEC, SAN DIEGO	PACIFIC
LT B. Welch	MOTU-2 NORFOLK	ATLANTIC
CDR J. Burritt	USS EMORY LAND (AS-39)	ATLANTIC

The AN/WLR Family consists of Electronic Warfare systems for both submarine and surface units. These systems provide emission detection capabilities. The two specific systems investigated were the AN/WLR-1 and the AN/WLR-6. Lack of parts support was the predominate problem as viewed by those interviewed. Apparently the poor parts support for the AN/WLR-6 is caused by the fact that it is being phased out, while the AN/WLR-1 is in the process of being overhauled to extend its life to the FY-88 time frame. The impression gleaned was that the organizational level in the surface fleet was quite capable of maintaining both systems if the necessary parts could be obtained. However, circuit board repair is not within the submarines' organizational level capabilities and, as such, requires the intermediate level to do the repair.

The AN/WLR-1 was introduced in 1958; it has undergone so many modifications that most operating units are not sure what series they have. The AN/WLR-1 is, due to age and use, in terrible condition and is a constant source of problems. Planned replacement by the AN/SLQ-32 has

suffered so many slippages in delivery date that the current WLR-1 rework program had to be initiated. A contract has been granted to Jonathan Corporation to refurbish it and provide parts support.

The major problem unit is the CV-741/742 which is a signal converter. It was planned to replace these with the CV-3599; an initial purchase was made of 50. Installation of the new converter has been credited with reducing the total system corrective maintenance by 80 percent. A primary problem is that, once the new unit was proven and the decision was made to replace all the CV-741/742's, no money was available for purchase of the additional units required.

RECOMMENDATION: On the premise that Jonathan Corporation will fulfill their contract, no recommendation is deemed necessary.

4. PP-6241/U

PROBLEM: The PP-6241/U is a power supply unit used with a radio for short-haul communications. This particular power supply enables the radio to be remotely powered. The problem is that demand information indicates that the organizational unit is ordering the next higher assembly, the entire power pack, instead of replacing failed parts, such as the rechargeable batteries, within the power pack.

BACKGROUND: Discussions were held with the following personnel:

NAME	ORGANIZATION	FLEET
Mr. J. B. Williams	NESEC, SAN DIEGO	PACIFIC
LCDR R. Tudor	SIMA, PEARL HARBOR	PACIFIC

The power pack itself works well and, overall, causes very few problems. (Mr. Williams observed that the companion transmitter-receiver, the RT-0524/VRC-46, was actually the subject of more casualty reports.) However, a problem does exist relative to the rechargeable batteries. The battery charger was extremely difficult for one organizational unit to get and, once they did get it, the charger failed to work. The charger is managed by the Army and was apparently never meant to be used aboard ship. There is also a fear that, if recharging were possible, the charger's lack of safety features could easily cause an explosion and lead to serious injury and damage. The organizational level's remedy for this equipment fault has been the ordering of the next higher assembly.

RECOMMENDATION: Make batteries a replaceable item or provide a battery charger that works and is safe.

5. RT-859A/APX-72

PROBLEM: The RT-859A/APX-72 is a transponder set that is used on both ships and aircraft. The inventory manager is the Aviation Supply Office (ASO), which means that requisitions for parts from ships are sent to ASO via SPCC. ASO views non-aviation requests from the Navy in the same way as it does those from other services. Thus,

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ASO may cancel the request on the basis that SPCC failed to properly forecast ship demands. The ability to properly predict demand becomes increasingly important and raises the issue of the repair capabilities of the fleet with regard to this transponder set.

BACKGROUND: Discussions were held with the following personnel:

NAME	ORGANIZATION	FLEET
Mr. R. Giarrantana	NAVELEX (Code 821)	N/A
LT B. Welch	MOTU-2 NORFOLK	ATLANTIC

According to Lt. Welch, the RT-859A/APX-72 is very difficult to troubleshoot and few surface technicians have the training required to repair it. However, he could not recall parts support as being a problem; it was Mr. Giarrantana that provided information regarding this aspect. Apparently, at one time, ASO managed only the air side, while NAVELEX managed the surface side. This was accomplished through the use of different stock numbers; ASO used the National Item Identification Number (NIIN) and NAVELEX used a temporary stock number (HCO). This worked well for projecting requirements but failed to support surface units when requesting replacement parts. Ships would use the ASO stock number instead of the HCO number, and turn in a carcass to ASO but were never assured of getting a replacement in "A" condition. Due to this failure and the push toward a one-item, one-manager concept,

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ASO was appointed as the manager. Unfortunately, ASO does not seem interested in providing the Navy's non-aviation customers with the same service as aviation customers.

RECOMMENDATION: ASO should modify their forecasting model to include surface requirements in accordance with the responsibilities of an item manager.

6. CU-937/UR

PROBLEM: The CU-937/UR is an antenna coupler used with the WRC-1 radio set. This particular coupler has been in use for several years. Corrosion prevention is accomplished by filling the housing with an inert gas which requires a seal to prevent leakage. The problem appears to be that the organizational level is not capable of resealing it after maintenance.

BACKGROUND: Discussions were held with the following personnel:

NAME	ORGANIZATION	FLEET
LT R. Sargent	NAVCAMS EASTPAC	PACIFIC
LT R. Quijada	NAVCAMS EASTPAC	PACIFIC
LCDR R. Tudor	SIMA, PEARL HARBOR	PACIFIC
Mr. J. B. Williams	NESEC, SAN DIEGO	PACIFIC
LT B. WELCH	MOTU-2 NORFOLK	ATLANTIC

The inner workings of the CU-937/UR are predominately mechanical. The technician must not only have electronic skills but must also be somewhat mechanically inclined. It is often much easier to order the next higher level assembly than to attempt repair. This solution is reinforced by the difficulty associated with resealing. An improper seal

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leads to corrosion, and there is difficulty in having equipment available to test the seal. The representatives of NAVCAMS EASTPAC's Consolidated Maintenance Office (CMO) felt that smaller ships without the luxury of a machine shop have no capability to test the seal, while Lt. Welch and the representatives of SIMA, PEARL HARBOR both concurred that facilities were available at the MOTU's and the SIMA's for ships requiring this capability and, as such, did not view resealing as that much of a problem. However, these facilities are only available when in port.

In an attempt to resolve the problem, two field changes have been developed. The first permitted sealing and then pressurizing but the problem then became one of overpressurizing and popping the seal. The second change was a kit (NSN: 4820-00-054-7713) which permitted the use of a tee and a pressure relief valve on a common port. The kit was to be available in August 1978. However, after purchase, the kits disappeared and the supply system is unable to locate them for distribution.

RECOMMENDATION: Provide fleet with field change kit (NSN 4820-00-054-7713) either by locating the lost lot or through a new purchase.

7. AN/PRC-56

PROBLEM: The AN/PRC-56 is a receiver helmet that was originally purchased in 1970. It is used on the flight deck of an aircraft carrier by the "yellow shirts" or

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supervisors. There are normally fifteen to twenty in use during flight operations. The purpose of the helmet is to permit communication with the air boss in the "tower" and the flight deck officer. The unit consists of pop-out replacement modules. Due to what appeared to be an extremely high demand for the entire unit, the question was raised as to whether attempts were being made to salvage working modules before turn-in.

BACKGROUND: Discussions were held with the following personnel:

NAME	ORGANIZATION	FLEET
LT R. Sargent	NAVCAMS EASTPAC	PACIFIC
LT G. Manuel	NAVCOMMSTA SAN DIEGO	PACIFIC
LT B. Welch	MOTU-2 NORFOLK	ATLANTIC

Lt. Sargent and Lt. Welch both agreed that the PRC-56 is inundated with problems. Because the helmets are used by flight operations personnel, ship's company does not claim ownership which greatly reduces their motivation to maintain the PRC-56. The design is poor; modules run hot and have a very short life expectancy. The alignment is impossible to maintain after minimal use and realignment is an extremely time-consuming job. Additionally, parts support is nearly non-existent; maintenance training is hard to get and if obtained, the value of it is questionable; the technical manuals are not useful and the test equipment is nearly impossible to obtain. The frustration that these problems induce, coupled with the total lack of

system support of the unit, justifies ordering the entire helmet.

Lt. Manuel had a completely different view. Taking into consideration the treatment received, the radio performs well. According to Lt. Manuel, the system requires return of the entire helmet in return for a replacement rather than just by parts. He suggested that if the ship developed a good maintenance program the bulk of problems associated with the unit could be overcome. The suggested maintenance program includes hoarding of good parts and building bad helmets to return to the system in exchange for the replacements. Additionally, a rigorous training program is required to ensure that an adequate onboard skill level is maintained.

RECOMMENDATION: In view of the many problems and the extraordinary efforts required to overcome them, it is felt that the most beneficial action would be to provide the fleet with a replacement set which is lightweight and throwaway.

C. SUMMARY

As is evidenced by every case study the information feedback system is not adequate for problem diagnosis. In each case, the problem, as interpreted by the support establishment, was actually a symptom. The ordering of the next higher assembly is not a result of lacking the

capability to repair but of lacking the proper equipment, parts or skills. This was true in the case of the AN/WLR-1 and the AN/WLR-6 which have both suffered from poor parts support, the PP-6241/U which has rechargeable batteries but not a functional charger, the CU-937/UR which without the proper testing equipment cannot be resealed and the AN/PRC-56 which lacks parts support, training, test equipment, technical manuals and durability. In the case of the AN/BRD-7 it is only the physical limitations of the submarine that restricts the organizational level's capabilities while the intermediate level is restricted only by the SM&R coding which dictates shipping to the depot for repair. In contrast, the AN/WRR-7 is an example of the organizational level accomplishing fault isolation beyond the level for which they are equipped. The organizational level has developed a means to surpass system diagnostics by utilizing the redundant features of the receiver to fault isolate to a single component. With the assistance of the IM level's 2-M capabilities the bad component can frequently be repaired, further reducing demand for replacement boards.

It is evident that the resources available at the organizational level are not being fully utilized. The modular replacement philosophy has led to an underrating of organizational-level skills which has, in turn, lessened the unit technician's responsibilities and greatly decreased

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the challenge and the satisfaction available. Factors such as these decrease the technician's motivation which adversely impacts performance leading to the reinforcement of a "swapping out" instead of a repair maintenance concept. Breaking this vicious circle requires the return of challenge to the technician's job and of providing the fundamental skills necessary to meet that challenge. This is the only way that self-sufficiency of platforms can be guaranteed. Technicians at the organizational level have the required capabilities. When provided with adequate training, skills, spare parts, test equipment and technical manuals, their only maintenance constraint will be that inherent to the physical limitations of their platform.

V. ALTERNATIVES FOR CHANGE

New initiatives that will serve as partial solutions to the Navy's maintenance needs consist of the 2-M program supported by the Automatic Test Equipment (ATE) Evaluation and the Reliability Centered Maintenance (RCM) initiative. ATE consists of the test equipment and test program sets which allow fault isolation of the PCB's down to the piece part level while 2-M provides the tools and the skills necessary to repair the PCB. RCM is a methodology for developing a "total" ship maintenance plan. These programs will more adequately equip the organizational and intermediate levels to do repairs but in no way are substitutes for basic skill training.

The necessity for the additional capabilities is not limited to a changing maintenance philosophy but is also driven by the change to the stock fund concept for certain modules. Built-in tests and self-diagnostics are relied on to isolate failures down to usually three boards. Under the old supply concept, all three boards could be turned in at no cost to the unit and three new ones issued. The stock fund concept forces the unit to purchase replacement boards. The reaction from the fleet has been a strong desire to avoid these purchases and to attempt repair. Providing units with the tools required to do these repairs

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appears to be delayed only by an official policy decision that details the approach to be taken.

A. 2-M PROGRAM AND ATE

The NAVMAT Modular Philosophy study, referenced previously, examined the possible approaches to modular repair and developed four alternatives, which were:

1. Provide the fleet with modular repair capability.
2. Provide the fleet with a modular screening capability.
3. Provide the fleet with a selective modular repair capability.
4. Provide the SIMAs with a screening/repair capability.

The study's recommendation was not to support any alternative because of a perceived need for further documentation. While the direction of the 2-M program and the ATE program is contingent on the alternative selected, the delays in determining this policy have not halted the progress of either program. Regardless of which alternative is chosen, there will exist a need for 2-M and ATE.

The alternative selection also depends on the results of two other studies. The first is the Support and Test Equipment Engineering Program (STEEP) Pilot Automatic Test Equipment (ATE) Evaluation sponsored by NAVSEA. STEEP's objective is to demonstrate the cost-effectiveness and the practicality of technicians testing and repairing electronic modules and PCB's using ATE. STEEP is responsible for developing the policies and procedures for screening

electronic modules at the organizational and intermediate levels of maintenance. Pilot facilities at Norfolk, Virginia and San Diego, California have successfully proven the value of the program.

Unfortunately, each model/PCB requires a unique test program set (TPS) for fault isolation. Development of these programs is costly because it is time consuming. The lack of a large number of different programs currently limits the effectiveness of the program. For example, a system, which is composed of over 200 different boards, may currently have only programs for 30.

An additional problem is the lack of standardization and control. The STEEP program has not resulted in the selection of one model tester for all Navy uses. Instead, individual project managers are pursuing system specific test equipment.

> There is not a management reporting system to prevent one project manager from procuring the same ATE, under a different contract as another project manager is procuring. In the same way, nothing prevents a PM from developing a new ATE requirement that could in fact be met by an existing piece of ATE. Without a coordinated ATE management system, proliferation of models will occur. [Ref. 24]

The second study, also sponsored by NAVSEA, that will have major impact on the level of repair policy decision consists of proposed tests to be conducted on selected DD-963's. The onboard module repair capability for digital PCBs of the MK86 Gun Fire Control System (GFCS) will be assessed with the objective of validating the anticipated

advantages of expanding the organizational level's capabilities. Two ships (one on each coast) equipped with test equipment, piece-part spares and documentation will perform onboard module repair over a one-year period. The technicians on these "module repair" ships will be provided with everything required for piece-part repair except training in fault isolation. The quality of repairs and the downtime will be measured. The maintenance performance on these two ships will be compared with that from a second set of two ships which will serve as the controls and will continue to use the present maintenance concept. [Ref. 25]

The test will also assess the ramifications and impact on training, documentation, sparing and should shed light on the personnel requirements issue. With the high reliability and low failure rate of new systems, increases in manpower should not be required.

B. RELIABILITY CENTERED MAINTENANCE

The far reaching implications that maintenance issues have on all phases of readiness has resulted in an increased awareness and elevation in importance of maintenance practices, policy and procedures. This increased emphasis was officially acknowledged in the Chief of Naval Operations (CNO) Objective #3 [Ref. 26] entitled, "Improvement of Material Condition of Ships in the Fleet," within which it was established that a major Navy priority was to develop

a program to promote an early improvement in the fleet's material condition. Achievement of CNO Objective #3 consisted of establishing the Ship Support Improvement Project (PMS 306) within the Naval Sea Systems Command, with a charter to undertake improvements for both the short and long term. It was through this effort that the Maintenance System Development Program (MSDP) came into being during 1977.

The goal of the MSDP was defined as helping the Navy improve ship maintenance functions to attain and maintain a specified realistic level of ship and equipment material readiness at least total cost. The MSDP initiative signifies the high level of importance that is being placed on maintenance. For the first time, maintenance requirements are to be developed and justified on system life cycle basis rather than being based solely on procurement costs. This reevaluation process is closely tied to the redistribution of responsibilities between the three levels of maintenance discussed previously, and the observed trend to increase the organizational level capabilities.

In view of the fact that ship maintenance consists of such a wide variety of functions and activities, the MSDP was undertaken as a multi-year, integrated study which would examine and recommend improvements to the many interlinked components of the Navy maintenance system. A major part of the study was conducted through a contract awarded to

American Management Systems, Incorporated (AMS) in Arlington, Virginia. The fundamental objective of AMS's MSDP was to address the primary components of an integrated maintenance system. One of these components consists of the initial process of determining requirements, which includes developing preventive maintenance plans, identifying probable corrective maintenance actions, recommending equipment redesign related to safety and mission requirements, and estimating initial maintenance resource requirements.

1. PMS Versus RCM

Economic pressures of the 1970's contributed to decreases in initial training, reduced manning levels and increased periods between overhauls. These factors motivated an increased emphasis on the Planned Maintenance Sub-system (PMS) of the Ship's Maintenance and Material Management (3-M) System which was introduced in the fleet in 1963. The goal of this detailed management system was to maximize the accomplishment of planned maintenance through the use of technically approved maintenance standards. However, by the early 1970's the general consensus was that the U.S. Fleet did not meet an acceptable standard of operational availability. Contributing to this impression was the fact that fleetwide implementation of PMS had not resulted in a significant improvement to fleet material readiness. [Ref. 27]

A twofold effort was initiated in an attempt to remedy the situation. The first was a request by the Commander in Chief, U.S. Pacific Fleet, in 1973, and endorsed by the Chief of Naval Operations, that the Navy Manpower and Material Analysis Center, Pacific (NAVMACPAC) conduct a study on various aspects of the Pacific Fleet 3-M Program. This study was to examine various aspects of the program, determine problem areas and recommend solutions to enhance fleet material readiness [Ref. 28]. The second was to analyze equipment maintenance requirements and develop a methodology for the determination of necessary scheduled maintenance to be performed by a ship's crew. This second effort was the subject of a subcontract issued by AMS to the Lockheed-California Company.

The findings of the NAVMACPAC study almost exclusively centered on poor administration of the program by the Type Commanders and management ineffectiveness at the shipboard level [Ref. 29]. The bottom line was that PMS specified tasks were not being done. As understood by this author, the tasks specified in PMS were based on technically approved standards provided by the contractor with no supporting documentation as to the validity of the tasks or the frequency with which they should be performed. Finally, a direct correlation was found between absolute neglect of PMS scheduled tasks and unacceptable material readiness, although none was found between selective non-accomplishment

and unacceptable material readiness. This fact led to the conclusion that time spent completing tasks which had no impact on operational availability was time wasted and that maximum maintenance effectiveness will best be achieved through the limiting of scheduled maintenance tasks to those that directly affect the operational availability of the platform. Additionally, it was observed by Lockheed-California that:

> Every maintenance action carries the potential of decreasing, rather than increasing, resistance to failure. Reducing the exposure of an equipment to unnecessary maintenance increases its operational reliability. Every potential maintenance action should be assessed carefully to ensure that it is likely to do more good than harm before it is adopted. [Ref. 30]

The issue was therefore not the existence of a scheduled maintenance program, but the philosophy behind content determination. PMS was designed using the philosophy that if an equipment is to be maintained a set of scheduled maintenance requirements should be established [Ref. 31]. As it is currently structured, PMS provides each unit with a set of scheduled requirements and the means to schedule, control and perform those requirements. Procedures for accomplishing each action are described on Maintenance Requirement Cards (MRCs), which also specify the skills and man-hours needed. The procedure for determining these requirements included an engineering review of the manufacturer's recommendations and operating experience documented by fleet feedback.

In contrast, the RCM strategy for the development of a maintenance program was to provide a methodology for validating the contents. The logic employed systematically determines: "(1) the need for scheduled maintenance; (2) the effectiveness of potential scheduled tasks from an engineering standpoint; and (3) the cost-effectiveness of potential scheduled tasks" [Ref. 32]. Therefore, a task will be scheduled only if it will prevent future failure and the benefit outweighs the cost. Thus, an RCM maintenance program for the Navy would have two objectives:

1. Preservation of the inherent design levels of reliability, performance and safety.
2. Accomplishment of this preservation at the minimum practical costs (in terms of system downtime, manpower, tools, materials, etc.) based on the criteria of the user. [Ref. 33]

Unfortunately, the determination of the relevant costs of RCM is quite difficult. Operational availability and self-sufficiency of platforms can not be achieved by translating their components to terms of merely dollars. In an operational environment any failure which jeopardizes the safety of the platform or the crew or that threatens mission accomplishment must be identified as requiring immediate restoral, even though frugal economic criteria may dictate otherwise. The offsetting benefit of repairing such a failure must be included in the analysis. As observed by the Lockheed-California Company's study team:

> . . . the optimal allocation of maintenance tasks must consider other factors than just the minimizing of maintenance cost alone. If such factors can be quantified reliably, even though it be in units other than cost, they can then be used along with maintenance cost, to identify the relative acceptability of a maintenance task. The cost and the benefit aspects of the maintenance task may take the form of a benefit-to-cost ratio. [Ref. 34]

The RCM approach implies also that the level of repair cannot be limited to the intermediate or depot level because organizational level capabilities must be able to handle the corrective maintenance defined by the RCM philosophy. In this respect RCM becomes all encompassing. Under its philosophy, defined maintenance actions and the division of labor between the three established levels are based on the same methodology whether they be in the form of a preventive or a corrective maintenance action. This not only encourages the inclusion of the organizational level into the realm of corrective maintenance, but also distributes preventive maintenance tasks throughout all three levels based on the same cost-effectiveness analysis. The relationship of preventive and corrective maintenance in the methodology differs only in that preventive maintenance analysis leads to the elimination of some tasks, the recategorization of other tasks, or to a recommendation for redesign. Corrective maintenance analysis always leads to a maintenance task. These tasks are not eliminated by economic or other constraints but are merely reassigned to a different maintenance level. [Ref. 35]

Clearly the RCM concept fully supports the Fleet Commander's in Chief objective of accomplishing maintenance at the lowest possible level.

> Under a philosophy which stresses that an unscheduled (corrective) task should be performed at the lowest level of repair in order to maximize availability of the affected unit, the criteria for making this determination are narrowly defined. Only the accomplishment of those tasks which by this very nature are incompatible with the physical construction of the ship or its requirements to be afloat will be deferred to intermediate or depot level maintenance facilities. [Ref. 36]

While there are drastic differences between the current PMS and RCM philosophies, they both share the same goal: increased operational availability through material readiness. This common goal supports the claim that implementation of RCM will cause little impact on the operating forces. The actual tools used in PMS accomplishment, such as the MRCs, will still be used under the RCM methodology. The change will be that assigned tasks will be minimized to those essential to failure prevention. The impact of this will, in most cases, be a decrease in time consumed completing maintenance tasks which are not mission essential. An additional change is that under RCM preventive maintenance becomes a subset of corrective maintenance while the 3-M system keeps the two as separate entities. Under RCM, the effectiveness of preventive maintenance can be measured by either reduced corrective maintenance or reduced total maintenance. "Both are driven by the basic principle that when maintenance of systems is accomplished to a degree

compatible with safety, and limited only to effective actions, the ensuing maintenance plan, if properly implemented, will assure high system availability at lowest expenditures of effort and dollars" [Ref. 37].

2. <u>Benefits of Reliability Centered Maintenance</u>

As was implied earlier, an immediate benefit of RCM implementation would consist of a savings in maintenance cost and, in the long term, there would be a definite potential for increased pride from the organizational level technician. The savings in cost were confirmed by a study conducted by Lockheed-California Company. A prototype RCM demonstration was conducted aboard the USS Roark (FF-1053). As a result of the RCM methodology, 269 systems and subsystems were analyzed and updated MRCs issued. The new MRCs included only those preventive maintenance tasks that were considered effective and necessary. Implementation of these revised MRCs reduced maintenance man-hours and the number of preventive maintenance tasks by 40 percent. [Ref. 38]

Such savings would also impact on the intermediate and depot levels. RCM justification for maintenance actions will eliminate unnecessary periodic rework and overhauls. "The greatest potential gain from RCM application may come from the elimination of fixed rework (overhaul) tasks. Substantial gains may also be achieved by changing on-condition inspections to failure monitoring tasks where no

safety-related functions are involved and the failure rate is high." [Ref. 39]

The other major benefit stems from the increasing of organizational level capabilities and responsibilities. By reducing the dependency of the organizational level on the intermediate and depot levels, the fleet technician will no longer perform only routine repetitive tasks, but will gain the freedom to perfect the skills necessary to maximize operational availability. This promises to instill pride and create a working environment with a greatly enhanced probability of job satisfaction which can, in turn, serve to further increase the level of self-sufficiency obtainable. However, implementation of RCM requires the caution that reaping such benefits will require strict adherence to program requirements. Poor administration and local management ineffectiveness will have similar results as did the implementation of PMS. While RCM logic supports completion of only tasks which are proven effective, the logic itself is no substitute for the proper performance of the actual task in assuring an acceptable level of material readiness.

3. Planned Implementation

The role of RCM in maintenance program development is defined in MIL-P-24534 (Navy) Appendix F, revised 15 November 1979. Implementation is currently limited to the preventive maintenance aspect, while corrective maintenance requirements continue to be governed by the previous LOR

analysis and 3-M procedures. Preventive maintenance task development, utilizing the RCM methodology, will be accomplished in two ways. First is the development for new systems and second is the development for existing systems.

Development for new systems requires the inclusion of the RCM methodology during the conceptual design phase of ship acquisition, when as part of the logistic support analysis, various support concepts such as reliability, availability, maintainability, initial life cycle support cost goals, and potential logistics problems are being identified. Inclusion of the RCM analysis at this early stage permits the maintenance planners to exert the maximum influence on design so that the ship can truly be designed to a goal of minimum maintenance.

Development of existing systems is under the cognizance of the PMS Coordinating Activities (the respective systems command). The coordinator assigns a developer for each system under its purview. Qualification for assignment as a developer requires successful completion of an RCM curriculum approved by the PMS Coordination Activity. The developer ultimately determines the applicable tasks that will prevent or detect failure; these will then provide the basis for the new maintenance plan [Ref. 40]. The intention of RCM is to "consider the total preventive maintenance program for a ship, irrespective of the level

of the maintenance resources assigned to perform the required tasks" [Ref. 41].

The problem with this latter intent lies in its limited scope of application. The basic premise of the RCM methodology fully supports the observed trends in the Navy's maintenance philosophy. Extension of the program to include corrective maintenance would compliment current program initiatives, such as the return to increased organizational level capabilities, deployment of ATE and the development of a selective 2-M repair capability at the organizational level.

C. SUMMARY

The stumbling block to organizational level repair is an absence of official policy direction. Study efforts and pilot programs, such as STEEP and the tests on selected DD-963's are initiated, reviewed and programs implemented without the coordination necessary to prevent duplication and misdirection. At the same time, the systems commands continue to design equipment to a modular replacement concept at the organizational and intermediate levels without regard to the capabilities established by STEEP, which also provides for the deployment of ATE to SIMAs, Tenders, SRFs, and other intermediate maintenance activities with a completion date of the end of FY84 [Ref. 42]. In fact, this plan to procure test equipment for the intermediate level

[illegible]

suggests that an approach to the modular philosophy has been implemented, even though the NAVMAT study results indicate that a preferred alternative can not be supported by existing documentation. However, NAVSEA (PMS-306) with NAVMAT's approval, accelerated the deployment of ATE from the end of FY85 to the current date of the end of FY84. This demonstrated lack of consistency between policy and actions highlights the dire need for coordination and the merging of pursuits into a single direction. This lack of direction coupled with a paucity of test programs and a proliferation of testers severely limits the effectiveness of ATE from the onset. Management and coordination are essential if a new maintenance philosophy is to fare any better than the old.

VI. CONCLUSIONS

There is an evident trend underway to increase the organizational level's corrective maintenance capabilities. Accomplishment of this change in maintenance philosophy requires centralized control of maintenance policy and procedures, coordination of the 2-M and ATE programs, increased supply support, improved training, and inclusion of other than cursory economic factors in the level-of-repair analysis.

The return to an emphasis on the organizational level performing both preventive and corrective maintenance in no way entails deemphasizing the intermediate or depot levels but strives only to alleviate a complete dependency on the latter for corrective maintenance. This action will increase the purview of the organizational level and will encourage a partner-type relationship between all three levels. This will enhance the probability that problems will be resolved at the lowest possible level and that there will be a significant increase in the attainable degree of self-sufficiency and the efficiency of the three-tiered maintenance approach. This approach encourages a progression of capabilities with the depot level performing only those tasks requiring an industrial capability.

[illegible]

[illegible]

[illegible]

[illegible]

An overview of the current maintenance structure clearly supports the need for change. The elements required to provide the lacking coordination do exist. The strengthening of the NAVMAT organization, or establishment of some similar group, to coordinate and enforce the pursuit of a single maintenance concept would enhance the systems commands' final product. This, coupled with an increased emphasis on bridging the gap between the operators and the planners, should solidify a one-Navy maintenance concept. The resolution of the "conflict" between a need for self-sufficiency and the need for economic systems acquisition must support the acceptance of organizational level maintenance, as defined by OPNAVINST 4700.7F, to include corrective as well as preventive maintenance functions.

Maintenance structural changes must also be made on the operational side. The extensive impact that this change in the maintenance concept has on all phases of operations necessitates the elevation of fleet maintenance coordination to a level similar to the Pacific Fleet's LOGPAC. It is this organization that should manage all maintenance support activities ashore and have a liaison position with each TYCOM to provide a coordination point for afloat maintenance support activities. This will ensure that at least one activity has a total picture of overall fleet maintenance requirements. Within this "maintenance type command" there should also be a liaison with representatives of the systems

commands to provide a bridge between the planners and the operators. This representative would also be responsible for determining the type and amount of technical assistance required. This would consolidate TA into one chain of command and prevent the duplication of efforts that currently exists in both fleets.

Consolidation is also required in the management of the ATE program. Procurement should be limited to a single tester and a concerted effort needs to be devoted to expanding the number of programs (TPS) available as soon as possible. Testers without a variety of test programs are of limited value. Additionally, dollars spent on test programs will, in the long run, provide a greater return than dollars spent on the extensive deployment of one or more types of testers.

Current implementation of the ATE program should also be restricted to the establishment of deployable teams in each fleet. While these teams would be permanently attached to the SIMAs, their mission would include deploying with tenders and major task forces to provide a fault isolation capability for deployed units. Support of units in-port requires that at least one team be retained ashore at all times. Once a significant TPS library has been established, deployment of ATE to all intermediate facilities could be accomplished.

Closely related to the ATE program is the 2-M program. Each fleet unit should have, at the very least, an emergency 2-M repair capability. This capability, coupled with the deployable ATE team which would accomplish fault isolation down to the piece part level for all units attached to the task force, should be more than adequate to support maintenance requirements. It is envisioned that 2-M capabilities would progress relative to ship size so that a carrier would have the equivalent of any other intermediate activity while a destroyer might only have an emergency repair capability.

Improved supply support is also needed. The results of the equipment case studies emphasize this fact. One way that supply support can be improved is to make as many requirements as possible known to the supply system through the computer file maintained by the Ship's Parts Control Center (SPCC), known as Planned Program Requirements (PPR). Such requirements include both quantity and date needed.

A second way that supply support can be improved is to consider the interrelationship between repair parts used in preventive or corrective maintenance action in the development of a ship's Coordinated Shipboard Allowance List (COSAL). The current COSAL development does not consider such relationships.

The Integrated Logistics Support (ILS) Improvement Project in NAVSEA is in the process of implementing both of

these suggestions and the approach is tied to the RCM concept. The first step in the approach is to establish a bill of materials for each preventive maintenance action. Then all items in the bill of materials are entered as PPR's for each scheduled preventive maintenance action expected during a deployment of the ship (in the private sector this approach is known as Material Requirements Planning or MRP).

A similar approach can be taken for anticipated corrective actions. However, the number of such actions during a deployment is not known for certain. Therefore some type of forecasting technique would be appropriate for estimating the probability of a corrective maintenance action being needed. A bill of materials will also be more difficult to develop. Work is currently underway to develop such a bill at the Naval Air Rework Facility (NARF) at Alameda, California in support of depot level repair.

The third way that supply support can be improved is to make requisition processing as easy as possible for the user. One such way is to provide the maintenance personnel with pre-expended bins of materials. Typically this is done for inexpensive items. Such a bin would be appropriate for a 2-M station; it could contain all the chips, resistors, capacitors, and other common parts needed in the repair of circuit boards. Another way is to reduce the number of interchangeable parts as seen by the user. This has also been done by the ILS Support Project. A list of

22,000 items has been consolidated into a list of 2,000 "common" items; each has a special code. A requisition citing that code can then be used with a cross-reference file to obtain a part. The latter should be used by the supply system rather than the maintenance personnel.

Finally, the user must be made aware of the importance of submitting a requisition to the supply system even if the part is known to not be available. The demand forecasting models used by the supply system need such information if the COSAL's are to be as responsive as possible. Shore-based installations also need to do this. Hopefully, the approach of reducing the number of interchangeable items that the ILS Improvement Project has adopted will facilitate this process.

The case studies are also evidence that the resources available at the organizational level are not being fully utilized. The modular replacement philosophy has led to an underrating of the organizational levels skills which has in turn lessened the unit technician's responsibilities, greatly decreasing the challenge and job satisfaction. Factors such as these decrease the technician's motivation; this adversely impacts performance leading to a lack of interest in doing any type of maintenance beyond "swapping out." Breaking of this vicious circle requires the return of challenge to the technician's job and the providing of the fundamental skills necessary to meet that challenge.

This is the only way that self-sufficiency of platforms can be guaranteed. Training courses must therefore be designed to provide the technician with the skills necessary to accomplish repair. Teaching component replacement is not sufficient. Equipping the technician with the basic techniques of troubleshooting, soldering, and fault isolation is the only way to restore this perceived lack of talent in the fleet to the capability it should have. The organizational level has the capability and, when provided with the adequate training, skills, spare parts, test equipment and technical manuals, their only maintenance constraint will be that inherent to the physical limitations of their platform.

Development of a maintenance plan based on the RCM concept complements the return of emphasis towards the organizational level. Included in the first phases of design, this methodology provides an LOR analysis based on other than cost factors. RCM is driven by the basic principle that, when a maintenance plan is developed with a goal of achieving a compatible degree of safety with actions limited to only those proven to be effective, the highest system availability at the lowest expenditure of resources will be achieved. It provides a means for developing "total" ship maintenance programs with the level of repair analysis constrained only by the physical limitations of the unit.

Of course, further research is required in all these areas. The effectiveness of the new maintenance philosophy hinges on the degree of system support provided. Without adequate training, spare parts support and the proper tools, an acceptable level of material readiness cannot be achieved. Every aspect of the support establishment needs to be evaluated to determine its impact on maintenance and its optimum contribution to a self-sufficient fleet.

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Naval Telecommunications Command Headquarters
Attn: Code 00
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